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The Effect of Mathematical Modelling Activities on Students' Mathematical Modelling Skills in the Context of STEM Education

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Abstract

This study was conducted to examine the effect of mathematical modelling activities on the mathematical modelling skills of secondary school students in the context of STEM education. The study was designed according to the embedded design, one of the mixed research methods. The study group of research consists of 66 eighth-grade students studying in a public school in the central district of a large province in the south of Turkey in the 2020-2021 academic year. While the criterion sampling method, one of the purposeful sampling methods, was used to determine the quantitative study group of the research, the maximum variation sampling method was used to determine the qualitative study group. On the other hand, in the context of STEM education, mathematical modelling problems, evaluation rubric and semi-structured interview forms were used as data collection tools in the research. As a result of the research; It was concluded that mathematical modelling activities in the context of STEM education positively improved the mathematical modelling skills of secondary school students. In addition, it has been concluded that the students who receive education with mathematical modelling activities applied in the context of STEM education gain different interdisciplinary perspectives, experience positive developments in their thinking skills, adapt to group work more easily, and increase their interest in engineering and technology.

Keywords: STEM education, Mathematical modeling, STEM-based mathematical modeling activities

Introduction

In today's world, it is essential that people who can adapt to technological advances acquire 21st century skills (NSTA, 2011) so that they can grow up more competent and better equipped. From this point of view, STEM education, as a combination of science branches such as science, technology, mathematics and engineering, emerges as an important paradigm for individuals to gain an interdisciplinary perspective in solving the problems they encounter in daily life and to develop their high-level thinking skills. These higher-order thinking skills are mostly referred to as 21st-century skills appear in various waysin different studies and research (Byee, 2010; Wagner, 2008; Windschitl, 2009). According to many researchers, these skills include high-level thinking skills such as critical thinking, estimation, problem-solving, and reasoning and social skills such as cooperation, entrepreneurship, communication, creativity, and innovation (English & Watters, 2004; NCTM, 2020; Partnership for 21st Century Skills, 2015).

From this point of view, one of the main purposes of the mathematics course is to provide students with problem-solving skills (NCTM, 2020; Partnership for 21st Century Skills, 2015; MoNE, 2018). Mathematics also contributes to 21st-century skills as a discipline that has been continuously developed for centuries and is essentially problem-solving (Mevarech & Kramarski, 2003), which has been finding solutions to the various and most interesting problems of humanity for many years. In this context, modelling mathematical modelling is one of the mathematics teaching approaches that helps individuals establish a relationship between mathematics and find different solutions to real life problems (Arleback, Doerr & O'Neil, 2013, Artigue & Blomhøj, 2013; English, 2016). modelling As one of the most important elements enabling the transition to STEM education, mathematical modelling can be defined as expressing and solving a problem encountered in daily life mathematically and adapting the mathematical solution to daily life (Berry & Houston, 1995; Cakiroglu & Dedebas, 2018; Doruk & Umay, 2011; Borromeo Ferri, 2006; Crouch & Haines, 2007; Blum & Leiß, 2007; Kaiser, 2017). Mathematical modelling studies use other branches of science such as science and technology, engineering, and mathematics, in solving daily life problems. In this context, mathematical modelling applications, together with an effective

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STEM education, significantly contribute to students' analytical thinking skills, problem-solving skills, and assimilation of technology-based learning processes (e.g., Cakiroglu & Dedebas, 2018; Doruk & Umay, 2011; Niss, Blum & Galbraith, 2007; Crouch & Haines, 2007; Kaiser, 2017; Lesh & Doerr, 2003; Mason, 1998; English, Hudson & Dawes, 2013; Kertil & Gurel, 2016; Lesh & Zawojewski, 2007).

On the other hand, when the studies on STEM education are examined in the literature, these studies mostly focus on teacher candidates (Bergsten & Frejd, 2019; Yildirim & Altun, 2015; Yildirim & Turk, 2018) and teachers (Weber, 2015; Du Plessis, 2018; Geiger, 2019) competencies and attitudes are examined (Yildirim & Turk, 2018). Studies with students (Atit, Power, Veurink, et al., 2020; Cho & Lee, 2013; Miller, 2019; Rozgonjuk, Kraav, Mikkor, et al., 2020) are mostly about academic success and are generally experimental studies (Bergsten & Frejd, 2019; Yildirim & Turk, 2018). Other areas of study for the STEM approach are scale development and analysis studies (Buyruk, & Korkmaz, 2016). As can be seen from the relevant literature, a limited number of studies examining STEM education and mathematical modelling activities together, generally; these are the opinions of teachers and students about the use of mathematical modelling as a tool in STEM education (Guder & Gurbuz, 2018-English & Mousoulides, 2015) and research on the application of mathematical modelling in STEM education (Bergsten & Frejd, 2019; Derin & Aydın, 2020; English & Mousoulides, 2015). However, within the available literature, no study has been found that examines the effect of mathematical modelling activities on students' mathematical modelling skills in the context of STEM education.

In this context, for example, Derin and Aydin (2020), as a result of their research in which they examined the use of the STEM education approach in teacher education, concluded that the STEM education approach provided significant and positive improvements in the mathematical modelling and problem-solving skills of teacher candidates. Similarly, Bergsten and Frejd (2019) concluded in their study that teacher candidates could successfully design innovative STEM activities using mathematics and mathematical modelling after the training they received for STEM education and twenty-first-century skills. Again, English and Mousoulides (2015) examined the bridge construction processes of sixth-grade students with a STEM-based modelling activity. As a result of the study, they concluded that the students understood the nature of problem-solving, carefully analysed the complex data involved in solving real-life problems, and produced more than one acceptable solution.

A limited number of studies (Bergsten & Frejd, 2019; Derin & Aydin, 2020; English & Mousoulides 2015), in the literature examining STEM education and mathematical modelling activities together. Based on this idea, this study was conducted to examine the effect of mathematical modelling activities on the mathematical modelling skills of secondary school students in the context of STEM education and contributing to the field. For this purpose, answers to the following questions were sought:
1) What are the students' pre-test and post-test problems regarding the results of mathematical modelling problems in the context of STEM education?
2) What are the students' views on the solution process of mathematical modelling problems in the context of STEM education?

Literature Review

Mathematical Modelling
Mathematical modelling can be defined as mathematically expressing a problem encountered in daily life and adapting its solution to daily life (Blum & Leiß, 2007; Quarteroni, 2009; Borromeo Ferri, 2006; Doruk & Umay, 2011; Crouch & Haines, 2007; Kaiser, 2017; Berry & Houston, 1995). According to Blum and Leiß (2007), the modelling process can be expressed as making assumptions by understanding and analyzing the real-world situation in the mathematical world and interpreting the result in the real world. In the mathematical modelling approach, real-world problems usually consist of interdisciplinary problems. However, many researchers have stated that mathematical modelling applications are one of the most important elements in the development of students' analytical thinking skills, problem-solving skills and the qualifications they need in the technology-based information age (e.g. Lesh & Zawojewski, 2007; Niss, et al., 2007).

On the other hand, the competencies required to perform the modelling process largely overlap with twenty-first century skills (Arleback, Doerr & O'Neil, 2013, Artigue & Blomhøj, 2013; English, 2016). In this context, many researchers emphasize that mathematical modelling should be given more place in school mathematics (Blum, Galbraith, Henn & Niss, 2007; Doorman & Gravemeijer, 2009; García & Maass & Wake, 2010; NCTM, 2000). From this point of view, mathematical modelling practices are frequently encountered in classroom activities as an important factor in developing students' critical thinking, generalization and abstraction skills (Boaler, 2001; Kertil & Gürel, 2016; Lesh & Zawojewski, 2007; Lingefjard, 2006; NCTM, 2020). The purpose of mathematical modelling; to reveal students' creative and critical aspects, to help them develop positive attitudes towards mathematics, to teach them to easily understand mathematical concepts, and to solve and formulate unique problems.

Many researchers on mathematical modelling have pointed out different modelling approaches (Borromeo, Ferri, 2006; Hıdıroglu & Bukova Güzel, 2013; Kaiser & Sriraman, 2006; Maaß, 2006). The most generally modelling approach consists of simplification, mathematization, interpretation and verification stages as a cyclic process. From this point of view, the simplification is more understandable to the visual skills of any problems encountered in real life and the students' visual skills. Mathematization can be expressed as the transformation of mathematical models that students create in their minds into mathematical expressions through symbols. Interpretation and Verification can be expressed as the accuracy of the mathematical models they form in their minds to be controlled by themselves and interpret the results according to daily life (Borromeo & Ferri, 2006; Maaß, 2006; Verschaffel, Greer & De. Corte, 2002).

Stem Education and Mathematics

STEM education is an interdisciplinary approach that covers the entire educational process from pre-school to higher education (Gonzalez & Kuenzi, 2012; Hom, 2014). Many researchers describe STEM education as an integrated approach that combines science, engineering, technology and mathematics disciplines with different subjects in daily life (Berlin & White, 2012; Cakıroglu & Dedebas, 2018). From this point of view, mathematical modelling also includes science, engineering and mathematics by dealing with open-ended real-life problems. Again, mathematics plays a very important role in the process of understanding and predicting the world, which is a fundamental purpose of STEM education. Therefore, experiencing real-life applications and mathematically modelling real-world situations are at the heart of effective STEM education (Fitzallen & White, 2012; Cakıroglu & Dedebas, 2016). In this context, mathematical modelling studies, which are one of the tools that enable the transition to STEM education, provide students with the opportunity to create models for the solution of real-life problems, enable students to develop thinking skills and use their science, and technology and engineering knowledge and designs in the problem-solving process (English, 2009; Chamberlin & Moon, 2006; Dogan et al, 2018; Zieffler & Garfield, 2009; Lesh & Caylor, 2007; Lesh, Hoover, Hole, Kelly, Post 2000; Shahbari & Peled, 2017).

On the other hand, STEM education teaches students to look at the problems they encounter in daily life with an interdisciplinary approach and provides opportunities for students to renew themselves and increase their capacities. Many researchers emphasize that with STEM education, students have made significant progress in becoming students who are interested in learning, actively participating in discussions and questioning (Breiner, Harkness, Johnson & Koehler, 2012; Kovarik, et al., 2013). In this context, it is very important to implement an integrated education model in schools with the STEM education approach. Integrated education improves students' ability to relate to real-world problems, their ways of thinking, their problem-solving and reasoning skills, their ability to use science and technology for mathematical concepts, and better understanding is achieved through interdisciplinary connections. Again, many researchers emphasize the importance that activities prepared within the scope of STEM education should aim to develop students' skills such as analyzing, producing, designing, expressing mathematically and communicating (Berlin & White, 2012; Bryan, Moore, Johnson & Roekrig, 2015; Bybee, 2013; Corlu, Capraro & Capraro, 2014). Content or context dimensions are the most used STEM approaches in implementing STEM education (Roehrig, Moore, Wang & Park, 2012). In this context, in the content dimension, the relevant fields are organized as a single field, and the program is prepared in a holistic way, while in the context dimension, a discipline is taken to the center and other disciplines are used to teach this discipline.

Method

This research, was carried out to examine the effect of mathematical modelling activities on theirs mathematical modelling skills in the context of STEM education and make a contribution to the field, was designed according to the embedded design, which is one of the mixed research methods. Embedded design are a pattern that emerges by taking one of the researcher's quantitative or qualitative research designs as the basis and embedding the other design (Creswell 2018; Creswell & Plano Clark, 2017). This study investigated the effect of mathematical modelling activities based on STEM approach on students' modelling success. In this study, a quasi-experimental design with a pretest posttest control group was used. In this process, the data obtained by taking the opinions of the students on mathematical modelling activities based on the STEM approach were also supported with quantitative data.

Study Group

The study group of research consists of a total of 66 eighth-grade students studying in a public school in the central district of a large province in the south of Turkey in the 2020-2021 academic year. In this context, 33 students in the study group, who were educated in the elective Mathematics Applications Course, were determined as the experimental group and 33 as the control group. The experimental group consisted of 15 female and 18 male students; the control group consisted of 17 female and 16 male students. In the determination of the study group according to the criterion sampling method, the students; It was taken into account that they regularly attend school, are open to learning new methods in teaching, have a more positive attitude towards the lesson, and participate voluntarily in the implementation process.

On the other hand, the study group consisting of 7 students, which is within the scope of the qualitative dimension of the study, was determined according to the maximum diversity sampling, one of the purposive sampling methods. According to the maximum diversity sampling, research should reflect the diversity of individuals who may be a party to the problem at the maximum level (Morgan & Morgan, 2009; Neuman & Robson, 2014; Patton, 2014). Within the scope of this study, the effect of mathematical modelling activities on students' mathematical modelling skills in the context of STEM education was examined according to the views of students with different mathematical achievements. Accordingly, two of these students have low, two have medium, and the other three have a high level of mathematics achievement.

Data Collection Tools

In this study, respectively Mathematical Modelling Problems in the Context of STEM education and Evaluation Rubric developed by the researchers as quantitative data collection tools; the Semi-structured Interview Form was used as a qualitative data collection tool. Information on data collection tools is given below.

1) Mathematical Modelling Problems in the Context of STEM Education

Mathematical Modelling Problems in the Context of STEM Education, prepared by using the related literature and covering multiple disciplines such as science, mathematics, technology and engineering in relation to real life situations. It consists of "Water Waste", "Electricity problem", "Biopsy" and "Bicycle Safety" problems. Within the scope of the validity of the problems mentioned above, the opinions of one expert in mathematics education and two experts in the field of STEM education were consulted. In this context, the "Waste Water" and "Biopsy" questions were rearranged according to the students' levels. In addition, these problems were applied as a pilot to five eighth-grade students, apart from the study group, and no difficulties were encountered during the implementation process.

2) Evaluation Rubric

In the study, the evaluation Rubric developed by Kertil (2008) was used to determine the proficiency level of mathematical modelling activities in the context of STEM education. In this context, the stages in the mathematical modelling problem process are given in Table 1.

Table 1. Evaluation Rubric education

Names and Descriptions of Modelling Skills	
A: Identifying the problem	A1: Making simplifying assumptions: A2: Clarifying the goal A3: Formulating the problem
B: Expressing and solving problem situations with mathematical formulas and equations	B1: Identifying variables, parameters and constants B2: Formulating mathematical expressions B3: Choosing and applying a mathematical model
C: Using verbal expressions to explain the solution	
D: Using graphical and diagram representations to explain the solution	
E: Checking against real life situation	

Each stage in Table 1 is evaluated as “No (0 points)”, “Missing (1 point)” and “Correct (2 points)”. Accordingly, the statement “None” indicates that the relevant stage was never observed in the solution process of the problem; the “Missing” statement indicates that the relevant stage is observed incompletely or incorrectly in the resolution process; The expression “correct” indicates that the relevant stage was observed fully and completely in the solution process.

Example; The scoring of the question named "Bicycle safety" in the Mathematical Modelling Activity in the Context of STEM Education is as follows:

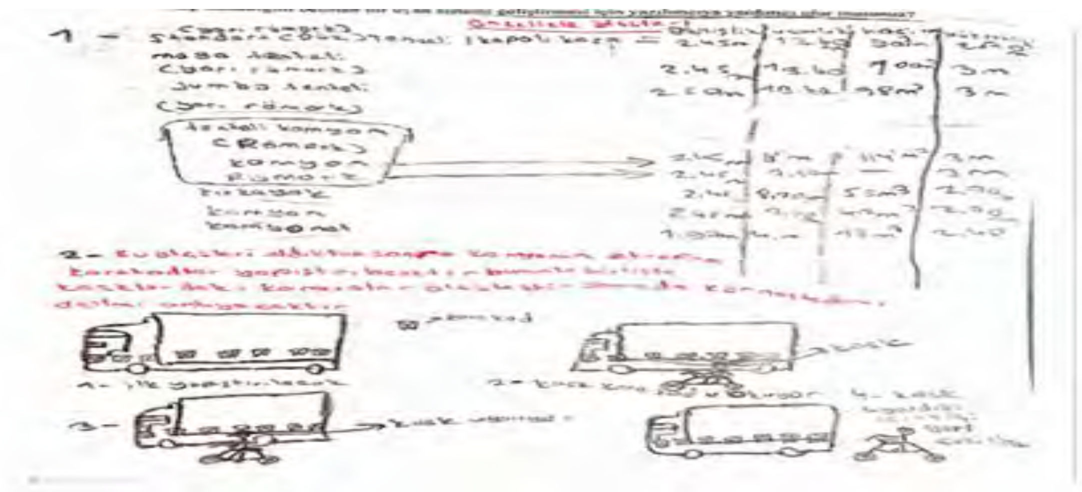

Figure 1. Solution example of student number 39

When Figure 3 is examined, the solution stages of the student were evaluated as follows:
Identifying and Simplifying Given (A1): At this stage, student 39 determined the variables for the solution of the problem. He obtained the dimensions of his heavy tonnage vehicles according to their types from their web pages. Thus, he determined the ones to be considered in the solution process of many assumptions (2 points)

Clarifying the Goal (A2): At this stage, he explained where the QR codes will be pasted, using the pictures. He clarified the target by choosing the one that is related to the solution of the problem among the many assumptions that can be considered for the problem situation (2 points)

Formulating the Problem (A3): At this stage, the problem is divided into sub-problems, such as sticking the QR codes and determining the blind spots of the warning systems in the helmets (2 points)

Identifying Variables, Parameters, and Constants (B1): At this stage, it was seen that the necessary variables, parameters and constants were determined to think routinely and reach the solution in the solution of the problem, but since there was no information about the calculation of the blind spots, this stage was evaluated as incomplete by the researchers (1 point).

Formulating Mathematical Expressions (B2): According to the solution of the problem, this step was under-scored (1 point) because the algebraic expression of the mathematical expressions stated verbally in the problem situation was missing.

Selecting and Applying a Mathematical Model (B3): This stage was considered incomplete because it verbally determined the correct mathematical modelling to solve the problem, but the calculations part was missing (1 point).

Using Verbal Expressions to Explain the Solution (C): Since the researcher used explanations for the solution of the problem in the verbal expressions of the group in this section, this stage was accepted as correct (2 points).

Using Graph and Diagram Representations to Explain the Solution (D): This stage was accepted as correct by the researcher since the representation of the solution was expressed with a figure (2 points).

Checking Against Real-Life Situation (E): It was accepted as correct at this stage since it was thought that testing the accuracy of the solution found in a real-life situation and, as a result, the solution process was planned. For example, researching the dimensions of heavy tonnage vehicles and using warning systems to identify blind spots for each of them is associated with daily life (2 points).

Examining Figure 3, and in accordance with the previous explanations, reveals that 39 coded students received a total of 13 within the scope of this activity.

3) Semi-Structured Interview Form
In the study, the semi-structured interview technique was used to examine the students' views on mathematical modelling activities based on the STEM education approach. In accordance with the purpose of the research, the use of improvised questions in addition to pre-prepared questions to obtain in-depth information from the participants is called the semi-structured interview technique (Fraenkel et al., 2012). The interview form prepared in this context was presented to the opinion of a STEM education expert and two mathematics education experts. The first question. The first question was re-expressed in line with the experts' opinions. The pilot study of the form mentioned above was carried out with two students other than the sample, and no problems were encountered in understanding and answering the questions.
Students participating in the interview were selected from the upper-middle-lower group of academic achievement in mathematics (Creswell & Plano Clark, 2017). During the interview process, the students were interviewed one-on-one for about 10 minutes. In the last stage, content analysis was performed on the obtained data, and appropriate codes and categories were defined.

Implementation Process

In this context, it was applied to the students as a pre-test in the first week of the seven-week implementation process and as a post-test in the last week. Only pre-test and post-tests were administered to the control group students; In the teaching process, the teaching approach included in the elective mathematics course and foreseen by the curriculum was applied. The tests and activities applied to the students in this process are given in Table 2.

Table 2. Implementation process of the study

Week	Application Name	Time
Week 1	Mathematical Modelling Problems in the Context of STEM Education Pre-Test (Stadium, Water Waste Problem, Bicycle Safety and Biopsy)	50+50 min
Week 2	Theoretical Information About STEM Education and Mathematical Modelling	50+50 min
Week 3	Mathematical Modelling Activity: Lemonade Sales	50+50 min
Week 4	Mathematical Modelling Activity: Height Footprint	50+50 min
Week 5	Mathematical Modelling Activity in the Context of STEM education: Electricity Generation	50+50 min
Week 6	Mathematical Modelling Activity in the Context of STEM education: Heat Insulation	50+50 min
Week 7	Mathematical Modelling Problems in the Context of STEM Education Post-Test (Stadium, Water Waste Problem, Bicycle Safety, and Biopsy	50+50 min

According to Table 2, in the first week of the application process, Mathematical Modelling problems in the context of STEM education were applied to the experimental and control groups, respectively, as a pre-test. During the application process, the experimental group was given information about mathematical modelling and its definition as theoretical knowledge, the definition and importance of the STEM education approach, and the problem-solving process. In the next stage, two mathematical modelling in the context of STEM education activities and two mathematical modelling activities were applied to the experimental group for a period of four weeks. In this context, each activity was applied to the experimental group by one of the researchers in the "Elective Mathematics Applications" course, which is two hours a week. On the other hand, in the control group, problems aimed at developing four-operation skills related to numbers and operations learning within the scope of the elective mathematics course were taught. Applications were applied to both groups by one of the researchers. At the end of the application, the mathematical modelling test in the context of STEM education was applied to the experimental and control groups as a post-test.

The practitioner scored the data collected to evaluate the process and the result with an evaluation rubric to avoid bias. The 'Heat Insulation', 'Lemonade Sale', 'Electricity Production' and 'Length Footprint' activities applied during the implementation process are from the relevant literature (Karahan, & Bozkurt, 2017; Yüksel et al.,2019; Dede and Bukova, 2018; Cavus Erdem et al., 2018) in line with the readiness of the students. Again, importance was given to the preparation of the applied activities with an interdisciplinary perspective depending on STEM applications and to the features that students may encounter in daily life (Çavaş, Bulut, Holbrook and Rannikmae 2013). Two experts in STEM education and Mathematical modelling during the preparation, implementation and evaluation of these applications opinions were taken. The activities were finalized in line with the opinions of the experts.

On the other hand, in the first stage of the research, the students in the experimental group were given detailed information about how the implementation process would take place, and the necessary approval was obtained from their parents. In the next stage, the students were divided into heterogeneous groups of 4-5 students and the necessary equipment and technological equipment were made ready. Heterogeneous groups were formed by bringing together students from different backgrounds, with the help of classroom teachers, taking into account the students' academic success. In this context, the common steps followed for the implementation of each activity throughout the teaching process are as follows:

1. After the students were asked interesting and interesting questions about the activity, activity papers were distributed. During the process, it was stated that the students could ask about the things they did not understand and were curious about.
2. After the activity papers were distributed, the students were asked to read the problem in the activity silently.
3. Students who read the problem with the information presented in the activity were asked to express the problem in their own words.
4. After each student wrote their statement, they were asked to research what information they needed to solve the problem. When necessary, he can benefit from the internet environment. In addition, if needed, tools such as cardboard, rope, glue, and scissors are available in the classroom environment.
5. In the next step, students were asked to write down the solution path they would follow to solve the problem. While creating the solution path, it was tried to give clues to the students where deemed necessary.
6. After the students created their solutions, they were asked to solve the problem by following the solution they created.
7. After making the solution, the students were asked to explain the contribution of the solution of the problem to them and to associate the solution with daily life.
8. In the last stage, the students were asked to explain whether the solution they found was effective and how they were sure of the correctness of the solution.

Throughout the process, the researcher tried to direct the students to think. In this context, the teaching process has been tried to be carried out in a way that makes the student active. During the implementation process of each activity, the students tried to solve as a group. Afterwards, the posttest was applied. In the last stage, one-on-one interviews were conducted with the students in the qualitative research group.

Data Analysis

The quantitative data obtained from the research were analyzed using the IBM SPSS 22.0 statistical package program. In this context, the data were analyzed according to the normal distribution Skewness and Kurtosis values. As a result of the analysis, it was concluded that the skewness and kurtosis values of the pre-test and post-test results of mathematical modelling problems within the scope of STEM education have a normal distribution (George & Mallery, 2019; Tabachnick & Fidell, 2019). In this context, independent groups t-test and Cohen's d analysis for effect size were applied. Again, in the interpretation of the effect sizes, the classification introduced by Cohen (1988) was taken into account, and the obtained value was found to be .35. In this context, the fact that this value obtained is greater than .14 shows that the difference has a large effect.
On the other hand, the qualitative data obtained from the research were analyzed by content analysis method. Content analysis is an analysis process that includes in-depth analysis of the data and creating codes and categories according to the concepts obtained from the data (Fraenkel, Wallen & Hyun, 2012). In this context, in the research, the interview data were coded independently by two researchers, and a joint decision was reached on creating the categories. In addition, quotations from student opinions were included to support these categories. Instead of the names of the students participating in the interview, coding as S1, S2, S3... was used according to the order of the interview.

Finally, within the scope of the reliability of the qualitative data analysis, support was received from an expert in mathematics education and experienced in STEM education as a second coder. In this context, the data obtained from the second encoder was asked to be recorded, and the agreement between the researchers and the second encoder was calculated according to the formula "Reliability=Consensus/Consensus + Disagreement". According to the result obtained, the concordance value between the encoder and the researchers was calculated as .92. A coherence value above .70 indicates that the codes and themes are reliable (Miles & Huberman, 1994).

On the other hand, within the scope of the ethical measure taken in the context of the research, all students and parents were informed about the content of the study at the beginning of the study by obtaining the necessary official permissions from the University ethics committee. Again, within the scope of ethical permissions, students and parents participating in the research were informed that they could leave the research at any time, and a signed parent consent form was obtained from those who voluntarily participated in the study. In addition, codes were used to keep the students' identities confidential and stated that all data would only be used within the scope of this research.

Results

Findings Concerning the Results of Mathematical Modelling Problems in the Context of STEM Education
Before the application, the students in the experimental and control groups were pre-tested on mathematical modelling problems in the context of STEM education, and the significance of the difference between the two groups was evaluated with the independent group t-test. In this context, it was concluded that the mathematical modelling problems of the experimental and control groups in the context of STEM education did not cause a significant difference in terms of pre-test results [$t(64)= -0.772$, $p>.05$]. Then, after the experimental process, the mathematical modelling test post-test scores of the experimental and control groups in the context of STEM education were analyzed with the independent group t-test. The findings are shown in Table 3.

Table 3. Independent Groups t-Test Results for Comparison of Post-Test Scores of Mathematical Modelling Problems in the Context of STEM Education

	Groups	N	$\bar{X}$	Ss	*sd*	t	p	*d*
Post-Test	Experimental Group	33	36.66	8.81	32	5.369	.000	.35
	Control Group	33	15.06	6.06				

When Table 3 is examined, it is seen that the mathematical modelling problems of the experimental and control groups in the context of STEM education cause a significant difference in terms of post-test results. ($t(32)= 5.369$; $p<.01$). Accordingly, it can be said that the students in the experimental group were more successful than those in the control group. However, the calculated effect size value as .35 also shows that the procedure performed in the experimental group had a great effect.

Within the scope of the second sub-problem of the research, the opinions of the students in the experimental group, in which mathematical modelling activities were applied in the context of STEM education, about the teaching process are given in Table 4.

Table 4. Student Views on Mathematical Modelling Activities in the Context of STEM Education

Categories	Codes	f
Cognitive Feature	Different Perspective	4
	Thinking Skill	3
	Better Learning	2
	Logical Thinking	1
Mathematical Literacy Skills	Increased Desire for Problem Solving	5
	Ability to Collaborate with the Group	5
	Ability Solve Real Life Problem	2
Contribution of STEM Education	Interest in Modelling and Problem Solving	3
	Engineering Field interest	2
	Technology interest	1
Affective Trait	Fun	2
	Beneficial	2

	Motivating	1
	Intriguing	1
The Difficulties Experienced	Difficult Problems	7
	Complex Problems	4
	Contains More information	1
	Joint Decision Making with the Group	1

As can be seen from Table 4, student views on mathematical modelling activities in the context of STEM education are grouped into five main categories. These categories are cognitive feature, mathematical literacy skills, contribution to STEM education, affective trait and the difficulties experienced. Accordingly, in the cognitive feature category, which is the first category, students state that they gain the most different perspectives and that STEM education improves their thinking skills. In this context, for example, the student coded S5 said, "We had a hard time solving-problems at first, but when we discussed it with friends, and we understood how we could solve the problem when everyone said something different. I always like to solve such problems. Because such problems allowed me to think better, make the right decision, have many possibilities, and have a different perspective while solving the question".

In the second category, in the context of mathematical literacy skills, students mostly state that their desire to solve problems increases, they can cooperate with their groupmates and easily solve real-life problems. In this context, for example, the student's interview coded S1 said, "We first had difficulties in solving the problems, but then we solved them easily. It was fun trying to solve the problem with our group mates. Different ideas of my friends made it easier for me to solve the question. I always want to solve such questions in mathematics."

Regarding the contribution of STEM education in the third category, three students stated that their interest in modelling and problem solvingproblem-solving increased. In contrast, the other two stated that their interest in the field of engineering increased. In this context, for example, the student coded S7 said, "We did not understand at all when we first started the activities. Then when it was explained and tried to solve, I saw many examples of questions. I heard different ideas and learned. From now on, I think I will understand more easily when solving problems. In the future, I plan to study STEM. I especially want to improve myself in the field of engineering."

In the category of affective trait, students stated that mathematical modelling activities in the context of STEM education are fun, useful, motivating and intriguing. In this context, for example, the student coded S2 commented, "The problems were fun, and they made us think. We can force our brains more in the face of a problem. This allows us to learn mathematics better. Since there are such problems in real life, I will no longer ask my teacher what mathematics will do for us. Now when I encounter such a problem, I think I will solve it."

Finally, in the final category of difficulties, students stated that the problems in the mathematical modelling activities within the scope of STEM education were difficult, complex, and overly detailed, and that they struggled to make a joint decision with the group in solving the problems. In this context, for example, student coded S6 said, "When I started the activities, I had difficulties with the problems. It was difficult for me at first because his problems were real-life related. However, as the group debated with their peers, these difficulties began to disappear. After that, things began to flow more smoothly. Then I understood how to think and solve in such events." expressed his opinion.

Discussion

In the context of this research, it was concluded that the STEM education provided caused a significant and positive difference in the post-test scores of the students in the experimental group compared to the students in the control group in terms of mathematical modelling. In other words, it can be said that theoretical education and given activities significantly increase students' mathematical modelling skills in the context of STEM education. Similar results were also obtained in studies conducted in the related literature (Arleback, & Albaraccin, 2019; Ceylan & Karahan, 2021; Derin & Aydın, 2020; English, 2016; Güder & Gürbüz, 2018; İncikabı, 2020; Mass & Engeln, 2019; Maass, Geiger, Ariza & Goos, 2019; Wiedemann, 2020). In this context, for example, Arleback and Albaraccin (2019) emphasize that mathematical modelling is at the center of STEM and that mathematical modelling supports the development of twenty-first century skills in STEM disciplines.

Again, Guder and Gurbuz (2018) revealed that mathematical modelling activities can be used as an interdisciplinary tool in STEM education, and that interdisciplinary mathematical modelling activities improve students' academic success and skills and cause positive attitudes towards mathematics. Similarly, Ceylan and

Karahan (2021) found that there were positive developments in students' knowledge and attitudes about mathematics and STEM fields after STEM-oriented mathematical modelling activities. In addition, Derin and Aydın (2020) revealed that mathematical modelling activities applied in the context of STEM education lead to significant improvements in both mathematical modelling competencies and problem-solving skills of pre-service teachers. Wiedemann (2020), on the other hand, revealed that in the context of STEM education, by combining computer-assisted mathematical modelling activities with real-world mathematical modelling experiences, students better grasp the solutions for the mathematical modelling process.

On the other hand, within the scope of the other sub-problem of the research, it was concluded that the students participating in the interview in the experimental group gained a different perspective with the mathematical modelling activities applied in the context of STEM education, they experienced positive developments in their thinking skills, they adapted to group work more easily, and their interest in engineering and technology increased. In this context, when the relevant literature is examined, it is seen that the studies conducted point to similar results (Derin & Aydın, 2020; Doruk, 2010; Güder & Gürbüz, 2018; Gümüş, 2019; Sağırlı, 2010; Zawojewski, Lesh & English, 2003).

Finally, in the study, it was concluded that with the help of mathematical modelling activities applied in the context of STEM education, students could more easily overcome the problems they encountered in real life and create many, alter, native solutions to them. Similar studies in the literature indicate similar results (Gümüş, 2019; Sandalcı, 2013; Sağırlı,2010). In this context, Sandalcı (2013), for example, revealed a positive increase in the level of noticing mathematics in daily life after the mathematical modelling activities ofsixth-grade students. Similarly, Doruk and Umay, (2011), as a result of their study on sixth and seventh-grade students, revealed that with the help of modelling activities, students experienced positive developments in their ability to transfer mathematics to daily life. Again, Sagirli (2010) found that with the help of mathematical modelling problems, 12th-grade students' ability to adapt, use and interpret mathematics to daily life improved. In addition, as a result of his study examining the interests and views of secondary school students in STEM education, Gumus (2019) revealed that STEM education increased students' academic success and caused positive developments in their daily life skills and awareness levels.

Conclusion

As a result, within the scope of this study, it was concluded that mathematical modelling activities in the context of STEM education positively improved the mathematical modelling skills of secondary school students. In addition, it was concluded that the students who received education with mathematical modelling activities applied in the context of STEM education gained different interdisciplinary perspectives, experienced positive developments in their thinking skills, adapted to group work more efficiently, and their interest in engineeri ng and technology increased. Accordingly, it can be suggested that more mathematical modelling activities based on the STEM approach should be included in the mathematics curriculum to raise individuals who can use mathematics more effectively in real-life problems and associate it with other disciplines. On the other hand, this study is limited to a seven-week education period with secondary school eighth-grade students. More comprehensive longitudinal studies can be conducted with students at different education levels in this context.

Author (s) Contribution Rate

All authors contributed equally to the article.

Conflicts of Interest

There is no conflict of interest.

Ethical Approval

Ethical permission (29 Mart 2021- E-95704281-604.02.02-65535) was obtained from Çukurova University Scientific in Social and Human Sciences Research and Publication Ethics Committee institution for this research.

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